



Transportation Synthesis Report

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Transportation, Air Quality and Health

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Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research.

REQUEST FOR REPORT

The pending reconstruction of the Marquette Interchange in downtown Milwaukee will increase the safe flow of traffic in a variety of ways. Drivers will no longer have to “white knuckle” it, trying to pick their way through several lanes of traffic when entering the freeway from a left-hand ramp and exiting to a right-hand ramp. All ramps will be placed on the right. Also motorists will find navigating the system’s curves much safer once most ramps are expanded to two lanes, distances between ramps are increased, and curves are lengthened.

However, concerns have been raised that the project also presents health risks. Specifically, The Sierra Club has cited research indicating that air pollution near high traffic areas increases the risk of serious health complications for nearby residents. These complications are said to include asthma, low birth weight and premature birth.

All of us, including transportation planners, recognize the importance of these concerns. The EPA established National Ambient Air Quality Standards to protect public health, including the health of sensitive populations such as children and the elderly, from adverse effects of poor air quality.¹ Transportation projects are subjected to rigorous state and federal environmental analyses.² Many of us also recognize that asthma and other ailments often tied to highway pollutants have numerous causes. To encourage a broader understanding of the causes, the RD&T Program was asked to review current available research. This is a preliminary report.

SUMMARY

We present our findings in three sections below, entitled **About Asthma**, **The Causes of Low Birth Weight**, and **The Facts About Preterm Birth**.

During our research, we also learned that major transportation projects can yield a number of environmental benefits—including cleaner air. For example, goals for the Marquette project include reducing traffic congestion. Idling, low-speed travel, deceleration and especially hard acceleration—which characterize congested conditions—all result in higher emissions than does travel at consistent, moderate speeds. Measures that smooth out traffic flow, reducing starts, stops and hard accelerations, can reduce emissions.³ Recent studies have confirmed that expanding roadway capacity can be an effective congestion reduction measure.

Below, we present additional data about the benefits of expanded roadway capacity and transportation investment in the section entitled **Transportation Investment: A Healthy Choice**.

ABOUT ASTHMA

Asthma triggers are everywhere in our environment: indoors, outdoors... Identifying triggers, however, is not always simple. It usually involves a process of elimination. A good place to start is a visit with the doctor, who may recommend a skin test for allergies.⁴ Asthma is thought to be linked to factors such as cold air and exercise, as well as exposure to substances that provoke an allergic reaction, such as house dust mites, animal fur, pollens and fungi. (Approximately 11 percent of the non-asthmatic population experiences exercise-induced asthma. Many of these people have allergies or a family history of allergies.⁵) Passive smoking, virus infections and changes in diet have also been linked to the condition. Scientists recently pinpointed a gene that has been found to be a major cause of asthma in a significant proportion of cases.⁶

Bacteria, stress and emotion are other frequently diagnosed causes of asthma. Research has concluded that maternal smoking can seriously impair infant lung function, even before the child is born. Experts agree that inhaled cigarette smoke increases the tendency of the respiratory tract to react to other asthma triggers. Babies and younger children are particularly vulnerable. In the elderly, the condition is less often of allergic origin, and more commonly associated with heart conditions or emphysema.⁷

According to allergy expert D.G. Wraith, in the report *Recognition of Food Allergenic Patients and Their Allergens* by the RAST Technique and Clinical Investigation: "Food allergy is a very important cause of asthma, but it is often overlooked. It is important because it may cause severe symptoms."⁸

Occupational asthma is caused by employees breathing in substances at work that produce a hypersensitive state in the airways and trigger a subsequent response in them. Not everyone who becomes sensitized goes on to get the clinical disease, but once the lungs become hypersensitive, further exposure to the substance, even at quite low levels, may provoke an attack. Work-related asthma is broader and relates to substances in the workplace that irritate the airways of individuals with pre-existing (e.g. childhood) asthma. Respiratory irritants may provoke attacks in those with occupational asthma or pre-existing asthma of non-occupational origin. Examples include chlorine, general dust and cold air. In this case, the individual does not become sensitized to that specific agent, but the attack is still work-related. Sometimes asthma symptoms appear several hours after exposure, possibly at night, so any link with workplace activities may not be obvious. Some sufferers become so disabled that they cannot work again.⁹

THE CAUSES OF LOW BIRTH WEIGHT

An additional concern presented by the Sierra Club deals with women who are pregnant and live near high traffic areas. The organization cited a study performed between 1994 and 1996, in which researchers observed an approximately 10 to 20 percent increase in the risk of premature birth and low birth weight for infants born to women living near high traffic areas in Los Angeles County.

Very little is known about the causes of low birth weight and preterm birth despite an extensive amount of research. Low birth weight that results from suboptimal intrauterine growth is associated with three major risk factors: cigarette smoking during pregnancy, low maternal weight gain, and low prepregnancy weight. These three risk factors account for nearly two-thirds of all growth-retarded infants. Other risk factors for low birth weight include first births, female sex, short maternal stature, maternal low birth weight, prior low birth weight birth, maternal illnesses, fetal infections, and a variety of metabolic and genetic disorders. While these risk factors may provide important clues about the causes of low birth weight, many of them are only weakly related to low birth weight.¹⁰

In 1991, 7 percent of all infants in the United States were born too small, and 11 percent were born too soon.¹¹ Since 1990, the frequency of low-weight births has increased in the Asian/Pacific Islander, White and American Indian populations. It has changed very little among Hispanics and has decreased in the Black/African American population, from 13.7 percent in 1990 to 11.1 percent in 2000. Babies are at higher risk of low birth weight if the mother is younger than 20 or older than 35, has less than 12 years of education, does not receive prenatal care, has poor nutrition or has a medical condition associated with low birth weight. Most cases of low birth weight are premature births (before 37 weeks).¹²

One of the more important clues about the causes of low birth weight and preterm birth comes from the observation that there are large ethnic group differences in these outcomes. African-American infants are two times more likely to be born low birth weight or preterm than are White or Asian-American infants. Epidemiologic research has shown that these group differences are not wholly explained by ethnic differences in the occurrence of various

medical conditions, in smoking or use of other licit or illicit drugs, in use of prenatal care, or by demographic characteristics and other lifestyle differences. Research is needed to discover potential biological or genetic differences between the racial and ethnic groups, which would distinguish between the low birth weight that occurs as a result of normal variability in infant size and the low birth weight that occurs as a result of environmental and/or biological injury.¹⁴

Although it is not clear how the mother's socioeconomic status translates into the birth of a low birth weight infant, it is thought that poverty with its associated reduced access to health care, poor nutrition, lower educational levels, inadequate housing, greater physical and psychological stress, and fewer life satisfactions may be responsible for some of the increased risk for low birth weight.¹³

While there are several things women can do to reduce their chances of having a low birth weight infant, one action stands out above all others—stop smoking cigarettes. Cigarette smoking is the single largest modifiable risk factor for low birth weight and infant mortality. It accounts for up to 20 percent of all low birth weight. Smoking retards fetal growth. On average, babies born to smokers weigh about one-half pound less than babies born to nonsmokers. Women who quit smoking during pregnancy significantly reduce the chances that their baby will be born low birth weight. However, most of these "preventable" low birth weight births would be concentrated among those infants born at or near term, who are moderately low birth weight, whose prognoses are quite good, and whose cost of medical care is moderate. Smoking is also associated with preterm birth, but this association is not nearly as strong as that for low birth weight.¹⁵

Experts believe that neighborhood-based care that is culturally sensitive and rooted in community values is a key factor in improving prenatal care.¹⁶

THE FACTS ABOUT PRETERM BIRTH

Every year more than 13 million babies are born prematurely across the world—many in developing countries.¹⁷

About half the women who go into premature labor do so for no known reason. Others may have a medical condition that contributes to early labor. In other words, premature birth can occur for a number of known and unknown reasons. These may include:

- A rupture of the bag of waters, the membranes surrounding the baby. Normally, these membranes rupture during labor or just before. But sometimes, they may rupture weeks, or even months, before the due date for no reason. In that case, there's a high risk that labor will begin within a few days.
- An infection of the uterus, cervix or urinary tract.
- A cervix that opens (dilates) without contractions (incompetent cervix). In a normal pregnancy, the cervix dilates in response to uterine contractions. But if the cervix is weak, it may open just from the pressure being put on the uterus as pregnancy advances. The cervix may have been weakened by a previous pregnancy or during a previous surgery on the cervix, such as a dilation and curettage (D and C) or a biopsy. There might also be problems with the uterus or cervix if the pregnant woman's mother was given the synthetic hormone diethylstilbestrol (DES), a medicine widely used from the 1950s through the early 1970s to prevent pregnancy complications. (DES is also used in a number of other situations: to treat atrophic vaginitis, menopause, hypogonadism, primary ovarian failure and in some cases prostate cancer. It is also used as postcoital contraception—the so-called "morning after" pill: <http://www.uhrad.com/mamarc/mam002.htm>) Other factors that may weaken the cervix include carrying more than one fetus or having too much amniotic fluid (hydramnios).
- Chronic diseases including high blood pressure, diabetes, kidney disease and hypothyroidism.
- An abnormally shaped uterus or a uterus with a benign tumor (fibroid).
- A previous premature delivery. Women who have had one premature birth have a 25 percent to 50 percent chance of going into premature labor again. For many women, though, early labor happens only once.
- Smoking, alcohol use or misuse of other drugs.
- Malnutrition.
- A baby with congenital defects.¹⁸

Many premature births happen with little or no warning. It may be that an infection involving the sack around the baby in the womb triggered the delivery. Some of the more defined, known causes of premature birth:

- Pregnancies with twins, triplets or more babies are very likely to end early.
- Stressful events like long distance air travel, the death of a relative or friend, or moving to a new house late in pregnancy can start labor early.
- Many babies arrive in a neonatal unit because of some emergency. It may be that the mother started to bleed or had high blood pressure, or that there was some problem with the umbilical cord or placenta.
- Pre-eclampsia occurs in about one in 14 pregnancies and causes around a third of all premature births (http://www.apec.org.uk/apec_what.html). It can be dangerous, particularly if it develops rapidly. Although bed-rest can help, the only way to stop pre-eclampsia is to deliver the baby early.¹⁹

The known risk factors also include low prepregnancy weight.²⁰

Prof. David Taylor, chair of the research advisory committee for WellBeing, says that lifestyle factors such as nutrition are recognized to play a role in the causation of preterm birth.²¹

Although working conditions may pose smaller risk increases for adverse pregnancy outcomes than do other medical or demographic factors in women's lives, working conditions remain a modifiable risk factor for preterm birth.

Since 1960, the number of employed women in the U.S. has nearly tripled, to 62 million. Between 1961 and 1985, the proportion of women working during the last trimester of pregnancy increased from 52 percent to 78 percent, and the proportion working within one month of delivery more than doubled (from 23 percent to 47 percent). This same time period saw a reversal in the trend of improvements in pregnancy outcomes that had been achieved during the 1960s and 1970s. The incidence of low birth weight increased from 6.8 percent to 7.4 percent of all births, while preterm births rose from 8.8 percent in 1980 to 11 percent in 1996.

Ellen L. Morzurkewich, M.D., and colleagues from the University of Michigan and the University of Washington, conducted a meta-analysis of 29 published studies involving 160,988 working women. Their study documents significant association between women's working conditions and adverse pregnancy outcomes. They evaluated the association between preterm births and mothers' working conditions: including physically demanding work, prolonged standing, long working hours, shift work and work fatigue. They also analyzed the association between physically demanding work and hypertension or pre-eclampsia and small-for-gestational-age infants. The researchers found a significant association between physically demanding work (defined as heavy and/or repetitive lifting or load carrying, manual labor or significant physical exertion) and preterm birth. Prolonged standing at work was significantly associated with preterm birth. Similar associations were found between both shift work and high levels of work fatigue and preterm birth. Physically demanding work was also found to be significantly associated with small-for-gestational-age infants and with maternal hypertension or pre-eclampsia.²²

TRANSPORTATION INVESTMENT: A HEALTHY CHOICE

A study prepared for the American Highway Users Alliance calculates the combined benefits of improving bottlenecks nationwide. This study estimates the benefits of improvements to the 167 worst bottlenecks* throughout the country, including major highway interchanges in cities such as Atlanta, Seattle and Denver. The improvements could reduce average peak-period delays from 25.2 to 6.2 minutes per vehicle trip, a 75 percent decrease. The improvements would also prevent 287,200 crashes over a 20-year period, including 1,150 fatalities and 141,000 injuries. Collectively, carbon dioxide emissions would drop by 71 percent; emissions of smog-causing volatile organic compounds would drop by 44 percent; and carbon monoxide would be reduced by 45 percent.²³

[*Wisconsin's worst bottlenecks- 1997:

Study ranking No. 146, Milwaukee I43 at reference milepost 72.080, 141,915 vehicles per day, 4,763 hours of delay
147, Milwaukee I894 at reference milepost 4.310, 112,040 vehicles per day, 1,585 hours of delay
148, Milwaukee I94 at reference milepost 309.841, 144,875 vehicles per day, 4,133 hours of delay
149, Milwaukee State Route 119E, reference milepost 1.890, 119,032 vehicles per day, 2,180 hours of delay]

“Because vehicle emissions rise sharply when speeds fall below 20 mph, increased congestion often means increased pollution (NCHRP- *The Environmental Benefits of Transportation Investment*).” Or, decreased congestion (through more lane miles and other strategies) often means decreased pollution.²⁴

Congestion may not be completely curable, but it can be relieved through targeted infrastructure investment. Metropolitan areas that have invested in road capacity in recent years have managed to stem the growth of congestion.²⁵

“Expanded capacity, particularly on routes that are carrying significantly more travel than they were initially designed to carry, results in improved traffic flow,” according to The Road Information Program (TRIP), a nonprofit organization that researches, evaluates and distributes condition, use and related information on highways and other transportation issues. TRIP has prepared congestion improvement studies for the states of California (<http://www.tripnet.org/CalifStudyMay2000.PDF>), Florida (<http://www.tripnet.org/floridacongestion.pdf>) and Washington (<http://www.tripnet.org/102041.pdf>). “Additional lanes on one route also have been found to reduce congestion on nearby routes by drawing some of the traffic from these secondary roads,” according to TRIP.²⁶

A TRIP analysis using data compiled by the Texas Transportation Institute compared increases in congestion levels and travel delays with increases in road capacity in 68 cities nationwide. The analysis found that areas that were more aggressive in increasing road capacity had 40 percent less congestion increase than areas that were less aggressive in adding lane mileage. The study also found that congestion increases as the amount of available lane miles per driver decreases. Cities with the highest level of congestion had, on average, 18 percent fewer lane miles per driver than the cities with the lowest levels of congestion.²⁷

According to an NCHRP report entitled *The Benefits of Reducing Congestion*, it is increasingly being said that we “do not have the resources to build our way out of congestion:

“Some argue that efforts to increase road capacity or speed traffic flow simply allow more people to drive longer distances,” the report says, “creating more traffic and leading to more congestion. In extreme cases, people argue that this ‘induced’ traffic will fill up the roadway near previous congestion levels, providing little or no benefit as measured in terms of congestion relief. It is indeed true that vehicle-miles of travel (VMT) have increased dramatically in recent decades. Evidence suggests, however, that the growth of the highway system is just one of many factors that have influenced the overall growth in vehicle travel.”²⁸

A report entitled *If We Build It, Will They Really Keep Coming? A Critical Analysis of the Induced Demand Hypothesis* points to additional factors influencing increased VMT, including population and employment growth, especially in metropolitan areas, and a decrease in the average number of persons per household, leading to more trips per capita for household-serving purposes.

“What we empirically observe is a disproportionate portion of extraordinary growth in urban travel that has oriented itself about corridors with improved levels-of-service,” notes the report. “Women entering the workforce and the consequent rapid growth in the total labor force, reductions in household sizes, and the increasing availability of private vehicles have all contributed significantly to post-war travel trends, but each of these factors has either already stabilized or is soon to reach a natural maximum. A fifth factor, the dispersion of residential and workplace locations, has also surely been a big determinant of travel, but the end of this trend at this point remains unclear.”²⁹

A number of studies in recent years have attempted to measure the “induced travel” effect, or the extent to which growth in transportation capacity results in additional travel. Studies that fully account for the range of factors influencing travel growth indicate that highway expansion may be responsible for only a small fraction of recent VMT growth.³⁰

A recent analysis of induced travel suggests that a highway improvement resulting in a 10 percent decrease in travel time would result in only a 1 to 4 percent increase in VMT – offering a clear net benefit.³¹

Overall, the nation’s air quality has improved considerably in the past 30 years, due in part to a reduction in motor vehicle emissions. Cars and trucks today run cleaner than ever before and emit significantly lower levels of carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOC, also called hydrocarbons or HC).

The introduction of unleaded gasoline has meant that emissions of lead have dropped to virtually zero. Tremendous strides in engine technology mean that the average car today produces 60 to 80 percent less pollution than the average car did in the 1960s. Overall, CO emissions from on-road vehicles fell 43 percent between 1970 and 1999. In contrast, CO emissions from non-transportation sources declined only 11 percent. Vehicle emissions of VOCs fell 59 percent, twice as fast as non-transportation VOC sources. NOx emissions from vehicles have increased—but only by 16 percent.³²

Through the Partnership for a New Generation of Vehicles program (PNGV), DaimlerChrysler, Ford, GM and seven federal agencies are collaborating in basic research leading to "breakthrough" technologies that could improve fuel efficiency by up to three times today's levels. The program strategically aligns basic scientific research programs at federal laboratories and agencies with vehicle manufacturers, suppliers and academia, in a cost-effective program to achieving important national energy and environmental goals. A key benefit is the achievement of societal priorities, such as improved fuel efficiency and reduced vehicle emissions, without substantial tradeoffs to consumers.³³

Foreign automakers are also researching and designing automobiles that increase fuel efficiency while reducing regulated emissions to levels that are below those of comparable vehicles today. One near-term option for a relatively fuel-efficient vehicle is a so-called "hybrid" power plant vehicle. Hybrids typically make use of two power plants, for example, a "conventional" internal combustion engine and an "unconventional" power plant such as an electric motor system or flywheel energy storage system. Toyota Motor Corporation recently announced the development of the Toyota Hybrid System. This hybrid vehicle makes use of an internal combustion engine, optimized for efficiency, a high-power battery and an electric motor/generator. This vehicle has been in production in Japan since December 1997.³⁴

In many cities, transportation investment is hastening the change to vehicles that run on clean alternative fuels such as compressed natural gas (CNG). For example, the Los Angeles County Metropolitan Transit Authority is overhauling its entire bus fleet, systematically replacing old diesel buses with clean-burning natural gas buses. Placing one CNG bus into service is the equivalent of removing the exhaust of 7.2 automobiles. In New York City, where taxis account for 10 percent of all vehicle miles traveled, a new Alternative Fuels Taxicab Program provides financial incentives for taxi owners to adapt their vehicles to run on CNG or to purchase new CNG vehicles. As a result, 300 CNG vehicles were operating in New York City by 1999, resulting in an annual reduction of more than 18 tons of VOC and seven tons of NOx. CNG-powered vehicles have another advantage over their gasoline-powered counterparts: on average, they emit almost 30 percent less CO₂ per mile traveled.³⁵

Regulations and voluntary programs designed to improve vehicle and engine technology are greatly reducing mobile source emissions. EPA studies show that today's cars emit 75 to 90 percent less pollution (for each mile driven) than their 1970 counterparts, thanks largely to advancements in vehicle and fuel technology. Still, further emission reductions are essential to further progress toward clean and healthy air for everyone.³⁶

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Prepared by Cambridge Systematics Inc., January 2002.

[http://www.transportation.org/community/reports.nsf/By+Category+Public/433B25EEC15E46B186256CFB004DE464/\\$FILE/WP2_NCHRP+8-36_Task+22_Paper+2_Environmental.pdf?OpenElement](http://www.transportation.org/community/reports.nsf/By+Category+Public/433B25EEC15E46B186256CFB004DE464/$FILE/WP2_NCHRP+8-36_Task+22_Paper+2_Environmental.pdf?OpenElement)

[An easily understandable document that effectively communicates the positive impacts of investments in this nation's transportation system. The work will be used by AASHTO in its TEA-21 reauthorization efforts. This is one of four working papers prepared by Cambridge Systematics, each covering an important aspect of the positive impacts of transportation investment.]

³National Cooperative Highway Research Program- *The Benefits of Reducing Congestion*, p. 8

Prepared by Cambridge Systematics Inc., January 2002.

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[An easily understandable document that effectively communicates the positive impacts of investments in this nation's transportation system. The work will be used by AASHTO in its TEA-21 reauthorization efforts. This is one of four working papers prepared by Cambridge Systematics, each covering an important aspect of the positive impacts of transportation investment.]

⁴Asthma Control- The Key to Management

Copyright Asthma-Control.com 2003. Page modified March 14, 2003.

<http://www.asthma-control.com/>

[This site discusses the symptoms of asthma and the wide range of triggers that can provoke an attack. It offers practical advice on how to identify and control triggers in the home, the workplace and the general environment.]

⁵About Asthma

Copyright About-Asthma.com 2002-2003. Page modified March 10, 2003.

<http://www.about-asthma.com/html/causes.php3>

[This site discusses the common causes of asthma—allergic and non-allergic—and the possibility of genetic predisposition to developing the condition.]

⁶BBC News- Health, July 10, 2002- *Gene causes many asthma cases*

<http://news.bbc.co.uk/1/hi/health/2119668.stm>

[Scientists pinpointed a gene that has been found to be a major cause of asthma in a significant proportion of cases. The scientists estimate that the gene could play a significant role in 40 percent of all cases of asthma.]

⁷About Asthma

Copyright About-Asthma.com 2002-2003. Page modified March 10, 2003.

<http://www.about-asthma.com/html/causes.php3>

[This site discusses the common causes of asthma—allergic and non-allergic—and the possibility of genetic predisposition to developing the condition.]

⁸Allergies and Asthma

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<http://www.allergies-and-asthma.com/>

[This site focuses on allergens that affect asthmatics and reviews allergens from the perspective of asthma sufferers, concentrating on those factors that can set off serious attacks and/or induce anaphylactic shock.]

⁹Health and Safety Executive (HSE)

Asthma- Causes: occupational asthma, work-related asthma

Page updated Feb. 13, 2003.

<http://www.hse.gov.uk/asthma/causes.htm>

[The UK's HSE and the Health and Safety Commission are responsible for the regulation of almost all the risks to health and safety arising from work activity in Britain. This site describes the main causes of occupational asthma, what it is like to get the disease, what employers have to do to protect their employees, what HSE and stakeholders are doing to tackle the problem.]

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http://www.futureofchildren.org/information2827/information_show.htm?doc_id=79929
 [This journal issue takes an in-depth look at what is known and what is not known about the major underlying cause of infant mortality and childhood morbidity—low birth weight.
 From article- *Low Birth Weight: Analysis and Recommendations*- Patricia H. Shiono, Ph.D., Richard E. Behrman, M.D.-“The Causes of Low Birth Weight and Preterm Birth” (p. 4)]
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 [Minnesota Milestones uses 70 progress indicators to determine whether the state is achieving 19 publicly determined goals. This link is to Indicator 8: low birth weight.]
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<http://news.bbc.co.uk/1/hi/health/1831519.stm>
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 [Site is owned by the Mayo Foundation for Medical Education and Research It provides useful and up-to-date information and tools that reflect the expertise and standard of excellence of Mayo Clinic.]
- ¹⁹BLISS- *Causes of premature birth*
<http://www.bliss.org.uk/support/causes.asp>
 [Site is managed by BLISS, a premature baby charity working to ensure that babies born too small, too early or too sick to cope on their own have the special attention they need from medical care to confident, well informed, loving families.]
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[Site is managed by the Office of Clinical Informatics at the Medical College of Wisconsin as a service to its patients and community. Goals include strengthening the sense of community among patients and physicians.]

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²⁷Frank Moretti- *The Best Solutions to Highway Congestion: Dispelling the Myths About the Impact of Expanding Roads*, p. II
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<http://www.tripnet.org/CongestionStudy.PDF>

[The Texas Transportation Institute (TTI), located at Texas A & M University, annually analyzes trends in congestion levels in 68 U.S. cities, including the nation's most populous urban areas. The TTI report provides a rich set of transportation data from 1982 to 1997 that highlights the trends in highway congestion in each community. This report, prepared by The Road Information Program (TRIP), is based on an analysis of the TTI data for the 68 metro areas and reports from the Federal Highway Administration.]

²⁸National Cooperative Highway Research Program- *The Benefits of Reducing Congestion*, p. 12
Prepared by Cambridge Systematics Inc., January 2002.

[http://www.transportation.org/community/reports.nsf/By+Category+Public/3DF1DCE37261D64D86256CFB004F8BCF/\\$FILE/WP2_NCHRP+8-36_Task+22_Paper+4_Congestion.pdf?OpenElement](http://www.transportation.org/community/reports.nsf/By+Category+Public/3DF1DCE37261D64D86256CFB004F8BCF/$FILE/WP2_NCHRP+8-36_Task+22_Paper+4_Congestion.pdf?OpenElement)

²⁹Mark Kiefer and Shomik Raj Mehndiratta- *If We Build It, Will They Really Keep Coming? A Critical Analysis of the Induced Demand Hypothesis*

[Presented at the 77th Annual Meeting of the Transportation Research Board, Paper No. 980937 (January 1999)]

³⁰Kevin Heanue- *Highway Capacity and Induced Travel: Issues, Evidence, and Implications*
Transportation Research Circular No. 481 (1998)

³¹Harry Cohen- "The Induced Demand Effect: Evidence from National Data," in *Working Together to Address Induced Demand*

[The Eno Transportation Foundation, with sponsorship from the Environmental Protection Agency and the Federal Highway Administration, brought more than 40 experts in planning, environment, land use, travel demand modeling, research, development, and government policy together to develop a better understanding of induced demand. Working Together to Address Induced Demand, a new report, summarizes the discussions at that forum, as well as includes several background papers. The report is available for \$35, plus \$5 shipping (\$25 to addresses outside US). Send orders to Eno Transportation Foundation, Dept. 3071, Washington, DC 20061-3071 (fax: 202-879-4719), or call Karen Dingler at 202-879-4702.]

³²National Cooperative Highway Research Program- *Environmental Benefits of Transportation Investment*, p. 2
[http://www.transportation.org/community/reports.nsf/By+Category+Public/433B25EEC15E46B186256CFB004DE464/\\$FILE/WP2_NCHRP+8-36_Task+22_Paper+2_Environmental.pdf?OpenElement](http://www.transportation.org/community/reports.nsf/By+Category+Public/433B25EEC15E46B186256CFB004DE464/$FILE/WP2_NCHRP+8-36_Task+22_Paper+2_Environmental.pdf?OpenElement)

³³Web site: U.S. Council for Automotive Research- PNGV
USCAR: 1996-2002

<http://www.uscar.org/pngv/partnership.htm>

³⁴*Evaluation of a Toyota Prius Hybrid System*, p. 2
EPA420-R-98-006, August 1998

<http://www.epa.gov/otaq/reports/adv-tech/priustst.pdf>

³⁵National Cooperative Highway Research Program- *Environmental Benefits of Transportation Investment*, p.5.
Prepared by Cambridge Systematics Inc., January 2002.

[http://www.transportation.org/community/reports.nsf/By+Category+Public/433B25EEC15E46B186256CFB004DE464/\\$FILE/WP2_NCHRP+8-36_Task+22_Paper+2_Environmental.pdf?OpenElement](http://www.transportation.org/community/reports.nsf/By+Category+Public/433B25EEC15E46B186256CFB004DE464/$FILE/WP2_NCHRP+8-36_Task+22_Paper+2_Environmental.pdf?OpenElement)

³⁶Web site: EPA- Solutions that Reduce Pollution

Web page updated Jan. 3, 2003

http://www.epa.gov/otaq/invntory/overview/solutions/vech_engines.htm